

Light Emitting Flat Panel with Embedded Light Guides Yielding  
Controlled Light Extraction for General Lighting Luminaire

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References Cited

U.S. Patent Documents

4422719	December, 1983	Orcutt	385/123.
4460940	July, 1984	Mori	362/558.
4471412	September, 1984	Mori	362/565.
4822123	April, 1989	Mori	385/31.
4765701	August, 1988	Cheslek	362/560.
5222795	June, 1993	Hed	362/558.
5836669	November, 1998	Hed	362/92.
6210013	April, 2001	Bousfeild	362/92.

STATEMENT REGARDING FEDERALLY SPONSORED  
RESEARCH AND DEVELOPMENT

The subject invention was not funded in any part by the United States Government.  
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BACKGROUND OF THE INVENTION

001 Numerous applications of optical fibers bundles to illumination are known. In most cases the fiber bundle is simply used to conduct the light to the remote location and the light is emitted from the open end of these fibers. In some instances, it is desirable to conduct electromagnetic waves along a single or collection of light guides and extract light along a given length of the guide's distal end rather than only at the guide's terminating face. This special need has been recognized in the prior art and numerous approaches to

the extraction of light at intervals from optical light guides or optical fibers have been proposed. Each of these proposals, however, has its specific shortcomings making the application impractical or limited to only a few situations.

002 For instance, Orcutt in U.S. Pat. No. 4,422,719, proposes the extraction of light from a light guide by enclosing the wave guide within a transparent sleeve having an index of refraction greater than the index of refraction of the wave guide and embedding within the sleeve light-reflecting powders, or by providing other discontinuities such as cuts or air bubbles within the fiber core. This approach has a number of shortcomings. First, the light extraction rate along the guide declines monotonically (and quite rapidly) from the proximal end to the distal end. The higher index of refraction of the cladding causes conversion of core modes (light propagation mode) to cladding modes to occur at the proximal end of the composite guide, thus sharply depleting the beam intensity as the light traverses the full length of the guide. Furthermore, the use of particles and bubbles suspended within the cladding causes excessive absorption of the light in the transmitting medium (particularly the cladding itself). Orcutt attempts to overcome the lack of light extraction control by including in the core refracting discontinuities or "light extraction" cuts through the cladding to the core and spacing these as a function of the distance from the light source. This approach is difficult to implement and furthermore, creates a series of discrete light sources along the guide and does not allow for continuous light extraction.

003 Mori (U.S. Pat. Nos. 4,460,940, 4,471,412 and 4,822,123) uses discrete light diffusing elements on a light transmission element to extract light from said light guide. In U.S. Pat. No. 4,460,940, Mori uses convex or concave diffusing elements to extract light of a specific wavelength, and a set of discrete elements with increasing density (but constant thickness) toward the distal end of the transmitting medium to extract light (presumably all wavelengths) from the transmitting element.

004 In U.S. Pat. Nos. 4,471,412 and 4,822,123, Mori uses discrete light outlets on a light conducting member. In the former patent he uses discrete diffusing elements without consideration to their quantitative light extraction capabilities while in U.S. Pat. No. 4,822,123 he uses light scattering discrete elements and simply increases their number as he approaches the distal end of the light conductor. The disadvantages of Mori's light

extraction systems include discontinuity of the light sources in that the appearance of the device includes a plurality of concentrated light sources, and the great difficulty in correctly spacing and sizing the extraction elements to provide for controlled light extraction from the light guide. Furthermore, the manufacturing and assembly of the devices of Mori is awkward and costly.

005 Cheslek U.S. Pat. No. 4,765,701 also uses discrete elements to extract light from an optical fiber in conjunction with a panel. Cheslek uses angular recesses and does not provide for means to control quantitatively the light extraction, and as a result, the illumination from the downstream (distal) recesses is progressively lower.

006 Hed U.S. Pat No. 5,222,795 proposed a curve linear tapering of the cross sectional area of a fiber optic and abrading or painting the flattened surface. Hed in U.S. Pat No. 5,836,669 then proposed the application of elongated triangular reflective stripes on to a plastic plate. The tapering of the fiber optics provided a one way illumination with a substantial amount of light that could not be extracted from the distal end of the tapered fiber perpendicular to the emitting plate face. The painted triangle method does not allow enough emitting area to make the light emitted practical for general illumination. The light injection end in both these applications do not provide enough distance for an even light flux and would cause a bright spot at the injection end. This condition on Hed's flat panel application is overcome by making the injection end part of the triangle very narrow and starting the installation of that triangle far from the emitting edge of the panel and thus further limiting the emitting surface.

007 Bousfeild U.S. Pat. No. 6,210,013, proposes a matrix of dots with increased diameters as they lay distal to the light injecting edge on a flat panel. This method is again limited by the actual area of reflectance.

008 The prior art as described is a two dimensional light propagation over a flat panel and thus the light output is limited by the actual area of the reflecting coating or treatment. The Light Emitting Panel herein described uses three dimensional grooves that have a surface area on two sides that is increased as it runs distal from the injection edge of the panel. The amount of light emitted is determined by the surface area and reflectance of the grooves.

## FIELD OF THE INVENTION

009 My present invention relates to the controlled light extraction from light guides cast, imbedded or machined into base plastic or glass panels that are fed light through one or more edges from a remote source. The plastic or glass panel have a high measure of light transmittance better than 91% and a refractive index of 1.49 to 1.51. Light is emitted from the face of the panel refracted from the machined surface of the light guides within the panel. The surface area of the light guides increases as they lay further from the light input end. The interior emitting surface of the light guides are treated to cause light refraction on their surface. High reflectance paint is applied to the interior sides of the grooves. Light is either emitted directly from the light guide surface through the face of the panel or from the reflected light from the back of the panel then through the face of the panel .

010 A tapered light guide injector that has the shape and size of the light flux transporting light pipe on one end and the shape and size of the light panel on the other end provides an area where light flux is arranged by total internal reflection to preserve the light flux etendue and distribute the light evenly across the light input edge of the light emitting zone.

011 The subject invention was created to replace fluorescent lighting luminaires or applications with a remote light source device to overcome the space requirements, heat production, maintenance requirements, and application limitations of common light sources.

## OBJECTS OF THE INVENTION

012 The principal object of the invention is to provide a method of and means for extracting light from an edge lit panel in a controlled manner so that drawbacks of earlier illuminating systems using other light guides are avoided.

013 Another object is to provide light guides within a panel from which light can be extracted in a continuous manner by the refraction or by the diffused reflection of a controlled proportion of the light traversing the optical transmitting medium.

014 It is a further object of the luminaire device to provide a method to efficiently extract light in a continuous and at a predetermined rate from optical other light guides.

015 It is yet another object of the luminaire device to provide linear light sources having a predetermined relative luminosity along their length.

016 It is still another object of the luminaire device to provide such light sources where the luminosity along their length can be constant.

017 It is a particularly important object of the invention to provide such light extraction systems from which substantially all the light entering the extractor's proximal end is extracted along the extractor's extraction zone.

018 A further object of the instant invention is to provide a light extractor from which a predetermined residual portion of the light entering the proximal end of the extraction zone is allowed to be emitted at the extractor distal end while the balance of the light is extracted along the light emitting zone.

### SUMMARY OF THE INVENTION

019 These objects and others which will become apparent hereinafter are attained, in accordance with the present invention in a method of illuminating an area which comprises the steps of:

(a) providing at least one elongated light guide within a panel parallel with a remote light source emission. Said light guide is installed in such a manner by casting machining or cutting the panel. The light guide has a progressive internal surface that is refractive in nature.

(b) modifying a portion of the surface over an extraction zone of the light guide to impart a generally irregular tetrahedron shape to the zone extending continuously from a narrow small cross sectional end to a wider and larger cross sectional end thereof and so that light traveling through the panel in a propagation direction from the narrow end to the wide end will emanate in an emanation direction transversely to the propagation direction, the zone narrowing in width in a spreading direction transversely to the propagation direction and to the emanation direction whereby an area exposed to the light emanating from the light guide is illuminated continuously along the length of the light emitting zone;

(c) and injecting light into the light guide ahead of said narrow end so that the light propagates in said propagation direction whereby the area is illuminated.

020 Thus, I extract light in an extraction zone of the light guide in a controlled manner by treating a portion of the light guide surface in the extraction zone of the panel so as to convert a portion of the light panel along the extraction zone into a light guide that has at least two surfaces that are treated in a manner to refract and reflect light perpendicular to the emitting face of the panel.

021 A surface of the core light guide exposed over the light-extraction zone can be rendered diffusively light emissive by abrading the surface, coating the surface and/or chemically treating the surface.

#### BRIEF DESCRIPTION OF THE DRAWINGS

022 The above and other objects, features and advantages of the present invention will become more readily apparent from the following description, reference being made to the accompanying drawing in which:

FIG. 1 is a diagrammatic perspective view showing a clear polymethylmethacrylate (PMMA) Light Panel with the location of multiple emitting light guides and the tapered light guide injection area;

FIG. 1-A is a diagrammatic perspective view showing of the Light Panel with multiple emitting light guides cut into the back of the panel and the reflective layer of RTV Silicone and mirror.

FIG. 2 is a larger cross section of the light guides cut into the light panel with the reflective paint layer applied into the grooves, the RTV Silicone layer and the mirror layer.

FIG. 2-A shows the relative depth of the groove cut from the small cross sectional area at the proximal end of the panel and a larger cross sectional depth at the distal end of the panel.

FIG. 3 is a perspective view showing the geometric shape of the light guide within the light panel.

FIG. 4 is a diagrammatic drawing showing the configuration of a remote light source attached to several light panels with light pipes.

#### DETAILED DESCRIPTION OF THE INVENTION

023 My present invention relates to the controlled light extraction from light guides cast, imbedded or machined into base plastic or glass panels that are fed light from a remote source. Light is emitted from a clear panel from the surface of the light guides within the panel. The surface area of the light guides increases as they lay further from the light input end. The interior emitting surface of the light guides are treated to cause light refraction on their surface. Light is either emitted directly from the light guide surface through the face of

the panel or from the reflected light from the back of the panel that is covered by RTV Silicone with a refractive index of 1.4 .

024 A tapered light guide injection area that has the shape and size of the light flux transporting light pipe on one end and the shape and size of the light panel on the other end provides an area where light flux is arranged by total internal reflection to preserve the light flux etendue.

025 The subject invention was created to replace fluorescent lighting luminaires or applications with a remote light source device to overcome the space requirements, heat production, maintenance requirements, and application limitations of common light sources.

026 Figure 1 shows two general areas of the light emitting panel; the tapered light guide section and the light emitting zone. Light entering the tapered light guide injection can be from any light source and can be conducted by any fiber optic or light pipe system.

027 Light flux enters the tapered light guide area from fiber optics or a light pipe and as such is highly organized as a flux rather than a wide spread beam. The tapered light guide provides an area where the light flux can be evenly averaged and distributed across the proximal end of the emitting area of the light emitting panel by internal reflection. Once the light flux enters the light emitting area, it encounters areas of refraction and reflection from light guides that are cut or cast into the light panel on one side (fig. 2, 2-A, 2C). These refraction/reflection light guides have an increased surface area as they lay more distal to the light flux injection area (fig. 2-C).

029 As the light flux travels parallel to the light refraction/reflection side and the emitting side the refraction/reflection light guide areas disrupt the light flux organization and cause skew rays to be emitted opposite the refraction/reflection side of the light panel. The light flux loses intensity as it travels through the panel and is emitted from the panel. The increased surface area of the refraction/reflection areas (fig 2-C) compensates for the light intensity loss as it travels through and emitted from the panel and thus light is emitted uniformly from the panel from the injection end to the distal end.

029 Excess light that is not emitted from the panel and travels to the distal perpendicular edge is reflected back into the panel.

